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DISSERTATION
ON
RIVERS and TIDES.

I N T E N D E D

To demonstrate in general the Effect of BRIDGES, CUT-
TINGS, removing of SHOALS and IMBANKMENTS; and
to investigate in particular the Consequences of such
Works on the RIVER THAMES.

RESPECTFULLY ADDRESSED

TO THE RIGHT HONOURABLE

WILLIAM BECKFORD, Esq;
LORD MAYOR of LONDON, CONSERVATOR
of the RIVER THAMES.

By ROBERT ERSKINE, Engineer, &c.

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L O N D O N :

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DISSEMINATION

RIVER SUNDAY



WILLIAM BECK

Mayor of London
of the River Thames

BY ROBERT HARRIS

OF W. D. D. N.

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London

A
DISSERTATION
ON

RIVERS and TIDES, &c.

IN Mathematics and Natural Philosophy, Reasonings and Conclusions are constantly deduced from Axioms, and Truths confirmed by Experiment: Cavil and Dispute are thereby avoided; for Consequences, evidently founded on the most certain Maxims, cannot be denied. In a Dissertation intimately connected with these Sciences, it would be unpardonable to deviate from so laudable an Example; the Data here required being few, and at first sight obvious. Three of the following Principles only are requisite to our present Purpose; the other two are added, to elucidate the Subject, to connect our Ideas, and to shew that the same Laws of Gravity must take Place in Fluid, as well as in Solid Bodies.

P R I N C I P L E I.

First then, it will be readily granted, that Water of itself cannot run up Hill; an Observation in Appearance so trifling, that the Mention of it would be subject to Ridicule, did not a great deal of what is afterwards to be said depend on this most certain Prin-

ciple : And, therefore, that the Inferences we are to deduce from it may be fully comprehended, it is presumed the expressing the same Thing more at large, will be readily excused.

Water then, at the Bottom of a Cavity, cannot of itself ascend, its own Gravity keeping it in a State of Rest ; from which it cannot be removed without the Application of a Force, so directed as, in some Measure, to act under it, and raise it up. For Example, let a Pit be dug in the Channel of a River, (the Declivity of which we shall suppose two or three Feet in a Mile) the Particles of Water, which first filled it up, would keep their Places in a State of Stagnation ; because the Direction of the Stream has no perceptible Tendency to descend into the Cavity ; if it had, there would have been a natural one there before : Therefore, the River would glide over the Pit only with more Facility than over the Rest of the Channel, and whatever ponderous Body was brought down by the Current, would be there deposited ; and consequently it would, in Process of Time, fill up again. This is so very plain, that it does not require Experiment to confirm it.

PRINCIPLE 2.

An elastic Body cannot rebound higher than the Place from whence it fell, without some given Force added to its own Gravity.

PRIN.

PRINCIPLE 3.

Nor can a Pendulum, in going up, describe a greater Arch than that through which it descended, even supposing no Obstruction; but as Friction every where intervenes, the Effect is always less than the Cause.

PRINCIPLE 4.

Similar to the Pendulum, Water, in running down, cannot acquire a Velocity which will make it rise above its Fountain: A Maxim confirmed by numberless Experiments, and on which much of the present Argument depends.

PRINCIPLE 5.

If a Stream of Water runs through any Notch or Aperture, and that which supplies it continues at the same Height, only half the Quantity will flow through half the Aperture, and so in any other Proportion. This is likewise an undoubted Truth, confirmed by every Experiment.

To obtain a clear Idea of the Application of these Principles to Rivers and Tides, several different Cases may be stated; that our Reasoning, from what would happen under certain supposed Circumstances, may be transferred to what does happen to the Things themselves: Which Cases, being founded on the above infallible Truths, may serve
for

for Data, or allowed Principles, to investigate the different Circumstances which occur in reality.

PROPOSITION I.

Let us then, in the first Place, suppose a Canal to be dug from the Shore of the Sea, and the Bottom to be upon a Level with Low-water Mark: If the Water be permitted to flow in as the Tide rises, supposing the Length of the Canal several Miles, High-water Mark, at the Extremity, would be lower than High-water Mark on the Shore: For no Velocity, it can acquire in Running, will make it rise above its Fountain*; and the Friction on the Bottom and Sides would prevent its being equal to it; the Sea not remaining a sufficient Time at its greatest Height to allow its ascending to a Level. Consequently the Level of High-water Mark, in every different Part of the Canal, would be higher or lower, according to its Proximity to the Sea, or its Distance from it.

P R O P. II.

Further, the greatest Part, though not all, of the Water, which flowed in on the Rise, would run out on the Ebb; because the Water having a less Fall to assist it in traversing the same Space on going out,

* Prin. 4.

than

than coming in *, the Tide would return before the whole can be evacuated.

PROP. III.

If the Aperture to the Canal be contracted one Half at the Entrance, only Half the Quantity will flow through it, in the same Time †; and as we supposed the Canal of considerable Length, if its Sides are perpendicular, the Water at the Extremity, and every where else, would then only rise to half the Height it did before.

PROP. IV.

We have already considered the Consequences of an artificial Cavity in the Middle of a Stream. Any Dam or Obstruction across a River has a similar Effect, in respect of the Stagnation of the Water below the Level of the Dam ‡. But here we must again distinguish, before we proceed farther, between Things natural and artificial; for those Hollows in the Channel, which are naturally made by the River, proceed from the Velocity of an accidental Current of Water from above, and the Direction of this Velocity, being the Cause of the Cavity, there must be a Current at the very Bottom: The Water, from the Force it acquired in going down, meeting in its Rise the Water which runs on the Surface, occasions these Whirl-

* Prin. 5. and Prop. I.

† Prin. 5.

‡ Prin. 1.

pools

pools we see at such Places. But from Works of Art no such Effects can follow; because every Dam, or other Obstruction, has a Tendency quite contrary to the foregoing Case; for, by swelling the River, it diminishes the Declivity of the Current; which, therefore, cannot acquire such a Direction as to affect the Particles of Water below the Level of the Dam: All the Water then, under this Level, must be in a State of Stagnation, and cannot ascend the Hill, or Bank, which opposes it: The Effect must, here, be the same as in an artificial Cavity; and whatever Sand or Sediment the River brings down, will be deposited against the Obstruction; which, by Length of Time, will raise the upper Bed of the River, at least, to a Level with the Dam.

Having considered Streams by themselves, and likewise the Effect of the Tide flowing up a Canal unobstructed by Water running down, let us now take a View of these two combined.

P R O P. V.

The Tide stopping the Course of a River, acts like a Dam: Let us therefore suppose a Dam made across the Stream; the Water, at the Dam and above it, would accumulate and rise, but never run backwards; because it could not rise higher than the

upper Part of the Stream, from whence it descended*. Now the Tide, obstructing the Current, is, to all Intents and Purposes, a most effectual temporary Dam; and consequently we may infer, that if the Quantity of Water, flowing down the River, could fill up the Channel to a Level with the Tide, which stops its Mouth, that is, if the Current was equal to the Tide; the River, in this Case, would rise and swell with the Tide, but never run backwards; the Equilibrium being preserved. Something similar to this happens in the higher Parts of Rivers, where the upward Current of the Tide ends; which Place we shall, on that Account, call the *Point of Stagnation*.

P R O P. VI.

Again, where the Water in the River is greater than the Tide, there the River will swell to the same Height; as if the Channel was obstructed by a Dam equal to the Altitude to which the Tide rises: Here the Current must still continue downwards, though its Velocity will be diminished, by reason of its Declivity being for a Time lessened.

P R O P. VII.

But if the Tide flows quicker than the River can accumulate to fill up the Channel, then

* Prin. 4.

the Tide will turn the Current. Therefore it is a certain Consequence, that wherever the Water of a River is, by the Force of the Tide, made to assume a Direction contrary to its natural Stream, the Level of the Sea is then above the Level of the River: For, as before observed, Water cannot run up Hill, and no Velocity it can acquire will make it rise above the Fountain from whence it springs*. To suppose that the Water, though running contrary to its usual Current, is higher than the Sea, is to suppose the Effect greater than the Cause, which is impossible. For this Reason we must naturally infer, that wherever the Tide runs upwards, High-water Mark on the Shore is above High-water Mark on the River. This Observation is founded on Principles so certain and obvious, that it cannot be denied, without, at the same Time, denying that the Laws of Nature are uniform. It is even clear, from daily Observations on the Tide, that its greatest Height is previous to the State of Stagnation. For it sinks before the Velocity upwards is lost; as may at any Time be seen in what the Watermen call the *Pinch of the Tide*. This happens from the acquired Force which continues the Current, after the Tide, from the Failure of its Source, has sunk to a Level; the Velocity is gra-

* Prin. 4.

dually lost, and the Water, pausing a few Seconds, till the Declivity turns the other Way, it runs back towards the Sea. The Inference then, here, is the same with that made from the Case of the Canal unobstructed by a River, that the High-water Mark, at Places nearer the Sea, is higher than at Places more remote, gradually to the Point of Stagnation, at which Point High-water Mark is lower than any other High-water Mark between that and the Sea. For this Point is the Meeting of two inclined Planes, formed by two opposite Currents, the one descending from the Sea, and the other from the higher Parts of the River.

Let us now compare the Quantities of Water from the Sea, and from a River, in their Congress, at any assigned Part of the River, where the Tide runs upwards; designedly, to point out a Way for determining the Proportion they bear to each other at the Place proposed.

P R O P. VIII.

We have already seen, that where the Quantities are equal, there is no upward Current*; consequently, wherever the Tide runs upwards, the Stream from the Sea is then superior to that of the River. It is meant by this Observation to infer, that the

* Prop. V.

B 3

Water

Water of the River alone, if dammed up, could not fill the Space above the supposed Dam, in so short a Time as it does when assisted by the Tide; the two, combined, being greater than either single: And that the farther the assumed Place is from the Point of Stagnation, the River of itself would be proportionally longer in filling that Space, which the Tide and River together fill in about six hours at farthest.

P R O P. IX.

If therefore the Quantity of Water in a River is measured, and the Space between High and Low Water Mark gauged (both which may be done with greater Accuracy and less Trouble than might at first Sight appear) the Proportion between the Tide and the River would be clearly ascertained *.

P R O P. X.

Fully to illustrate the Intention of these two last Propositions, let us suppose, that, where the Tide rises sixteen Feet, the Water of the River alone, if dammed up for the same Time that the Tide obstructs it, would rise four Feet; we must conclude, the Stream from the Sea to be three Times greater than that of the River, the Tide filling twelve, and the River four Feet: Now this Superiority of the Tide evidently depends on the

* There may, perhaps, be other Ways of determining the Proportion, from Theory; but this seems the most simple and obvious.

Capaciouſneſs of the Channel : Let us then ſuppoſe the Aperture to be contracted one Half, moſt certainly only one Half of the Tide Water could flow into the ſaid Channel; which, of Conſequence, muſt diminifh the Altitude of High-water Mark fix Feet : And tho' the Difference would not be perceptible juſt at the Point of Obſtruction or Aperture, in any other Manner than by a viſible Slope and the Rapidity of the Current; yet, at a moderate Diſtance above it, the Tide would only riſe ten, where before it roſe ſixteen Feet. It will readily occur, that, in this Way of Reaſoning, the Banks are ſuppoſed to be perpendicular, and the Breadth and Depth uniform; for if the River upwards is more capacious in one Place than another, the Altitude of the Tide would be proportionally leſs.

From theſe Data, the following Corollaries, or Inferences, naturally ariſe.

1. That the Sea, at High-water, is much higher than many Parts of the Earth; which is evident, among other Reaſons, from the Velocity of the Tides in Rivers: And were that Height, which in reality is inſtantaneous, to continue a few Hours, immense Tracts of Land would be overflowed.

2. That it is practicable, by building of Piers, ſo to contract the Mouth of a River, that the Tide ſhall flow up but a very little

little Way †. For Example, were Piers run from the opposite Shores at *Gravesend*, till the Channel was contracted to the Width it is at *Putney*, the Tide would hardly be perceptible at *Long Reach*, and at *London Bridge* we should have a constant Current downwards, and no Tide at all. This Method, however detrimental in the foregoing Case, might be put in Practice, with great Propriety, where Tracts of overflowed Land were to be gained and preserved from the Sea; it being much more certain, cheap, and expeditious, than imbanking a whole River on both Sides.

3. That as contracting the Mouth diminishes the Tide, so enlarging the Entrance, or any other Part of a River, where it is too narrow, will increase the Tide, and make it flow higher.

4. That the proper Shape of a River, for receiving all the Advantages it can acquire from the Tide, is that which gradually widens towards the Sea, like a Speaking Trumpet: And its proper Breadth, at every given Place, may be determined mathematically, supposing its Depth to be uniform.

5. That Uniformity in the Bed of a River is absolutely necessary; for whether the Area of the Channel be contracted one Half, by the visible Running out of a Pier, or the in-

† Prop. X.

visible Swell of a Bank, the Tide above must, in either Case, be equally diminished †.

6. That cutting through Land, to diminish the Windings of a River, provided the Cut be proportionally wide and deep, would, in many Cases, be very beneficial, and always increase the Tide upwards.

7. In fine, we have here a natural Solution of those Phenomena, which have happened in diverse Parts of the World; where large Tracts of Land have been by Nature rescued from the Sea: For Rivers naturally carry the Sand to their Mouths, where it forms Banks, which gradually, as they increase, diminish the Tide in the River: These, together with the Ouze which the Land-floods deposit, evidently occasion the Ground, which was every Tide covered with Water, to become at last dry Land. And thus we see, that those natural Operations, which to a cursory View appear pernicious, are, in reality, necessary to prevent Countries from being again overflowed. The Reverse will account for Inundations in some Cases, where those Banks or Dams have been removed either by Art or Nature.

Let us now apply those Principles to the River Thames.

Though, undoubtedly, there are several Places between *London* and *Gravesend* which

† Prop. X.

require

require Inspection; yet, whoever views the River, must first stop short at *London Bridge*, and ask how that Fabric affects it.

Here the River is dammed up to a considerable Height. To make the Effect of this Operation more manifest, let us suppose it still dammed up higher, even till the Water above Bridge be raised at all Times to High Water Mark; the Consequence would be, that above Bridge there would be no upward Current at all*; and, below Bridge, though the River would rise and swell just as high as at present, yet there could be no perceptible Current upwards near *Blackwall*, and perhaps lower; for six Hours Run of the Thames would fill about that Space of itself, being there met by the obstructing Tide†. Consequently, from the long Stagnation, occasioned by the Want of an upward Current, Banks would be formed; which, in a short Time, must diminish the Depth of the River every where but at the Fall. The Depth would, in Time, diminish above Bridge, from the dead Water below the Level of the Dam‡, though without producing so sudden an Inconvenience, on account of the greater and constant Depth of Water gained; but which, on every Flood from the Land, would overflow the Inhabitants of the lower Parts of *Westminster*, *St. James's Park*, and the *Borough*, for want of a free Passage at the

* Prop. VI. † Prop. V. ‡ Prop. IV.

Bridge. Whatever would be the Case, in an eminent Degree, on the foregoing Supposition, must be so in a less Degree, as the Bridge now stands. At present, as we must consider it in the Quality of a Dam, it greatly diminishes the Velocity of the Tide both above and below; and, by forming Banks, raises the Bed of the River below Bridge, where deep Water is most necessary: Above Bridge, the Increase of Banks is visible to every Observer.

When the great Arch of the Bridge was opened, the Increase of Water-way very sensibly diminished the Fall; and, without Doubt, while the free Passage remained, the Tide running farther and faster up the Country, must have been as perceptible. But to recover the lost Fall, for the Sake of the Water-works, several different Measures were taken; and, on every Emergency, the most experienced Engineers were consulted; but still in such a Manner, that they were limited to give their Opinion solely on the most proper Manner to preserve both the Bridge and the Water-fall: Several Arches were stopt up, and the Lightermen, of course, intrapped in the Eddy. Afterwards, of two Evils the least was chosen, and instead of some Locks being entirely barracadoed, they were partially dammed up with Wheels. At one Time the Current under the great Arch had so undermined the Starlings, that, in the Opinion of some ingenious Gentlemen the Bridge was

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within

within a Fortnight of falling down. On this Exigency, the Depth was diminished by throwing in about a thousand Tons of Stone; and as the Head of Water must, at all Events, be preserved*, the Bed of the River in general is so raised, that, from a very accurate Drawing, it appears, the mean Depth of the River under the Bridge, at *Dead-water*, is scarcely eight Feet, some Arches being only five, and others not even so much; therefore, at *Low-water*, it must still be more shallow. This Dam, which ever Way the Current sets, occasions all the Water below its Level to stagnate†, and makes it drop that Sediment upon its Channel, which Nature intended to deposit in the Ocean. The Effect is very sensibly felt, especially to the Westward; and the Banks between *London* and *Westminster* Bridges are very great, and must every Year increase. Though the Sand does not remain just at the Dam itself, on Account of the Narrowness of the Channel, and the strong Current which again carries it upwards; yet, when it arrives at a Place where the River is wider, and the Stream more gentle, near *Somerset House*, it there subsides. By how much, therefore, the Bed of the River is raised at any particular Part, by so much must the Bed in Time rise for a great Way above, to its manifest Detriment: Frustrating one of the great Designs of Providence in the Tides, the easy and al-

* By Act of Parliament!

† Prin. I. and Prop. IV.

ternate Communication up and down Rivers, by the ebbing and flowing of the Sea.

Let us now enquire into the Effect of this Dam upon the Tide. The Proportion of Water-way, between the Starlings and Breadth of the River, is nearly as one to four; and, between the Piers, as five to nine: If we say, therefore, that *London Bridge*, from the Bed being raised, by the Starlings, by the Piers, and by the Water-works, with their Appurtenances altogether, stops up only Two-thirds of the Water-way, we shall calculate most tenderly in its Favour*. It has been shown in our Data what must be the Consequence of such a Diminution of the Area of the Channel†; and were it ascertained (as proposed by Prop. IX. and X.) in what Time the River alone would fill the Space now filled by the River and Tide together, the real Loss it is at present to the Navigation upwards, and the considerable Advantage that would arise from enlarging the Water-way, could be fully proved. It has been demonstrated, however, that an Alteration would be very beneficial to the River in general, and in the End advantageous to the City; as the Sums expended on keeping so impolitic a Dam in Repair, only for the Emolument of a private Company, are very large, and must

* To shew that this is not exaggerated, the following are the Dimensions, taken from actual Survey. The Breadth of the River at *London Bridge*, is 934 Feet 7 Inches. Water-way between the Starlings, 238 Feet 2 Inches. Ditto between the Piers, 513 Feet 2 Inches.

† Prop. III. and X.

every Year increase ; which Sums might be laid out to much better Purpose in building a new Bridge. For there can be little Doubt that the Town might be as well supplied with Water otherwise,

It was alleged, as a Reason for raising the Bed of the River under the Bridge, that, at Low-water, the River was so shallow upwards, as to impede the Navigation ; Though in what Part this Stoppage was, or whether the Place was at all mentioned, I cannot now recollect : However, if it was so, it might be discovered by a proper Survey, without any Necessity of repeating the Experiment. In the mean Time we shall take it for granted, that at Low Water, in some Parts, Barges were at that Time a-ground, and prevented from coming down ; Yet it is no great Presumption to say, that this Inconvenience, if it should again occur from an enlarged Water-way, would be considerably overbalanced by the Advantages on the other Side ; though, on Consideration of the Consequences to be deduced from Prop. II. the Water might not be so shallow, as on a slight Review may be supposed. The greater Quantity flowing up, must still add to the Depth in returning, and the increased Strength of the Current both Ways, would likewise soon remove many of the Banks, and deepen the Channel ; and if there were any Parts where the Water continued too shallow, a very little Assistance
from

from Art would soon clear a Passage at Low-water.

To Craft going upwards it would be much more advantageous than now; for the Flow of the Tide would turn the Current sooner than at present (it is supposed by, at least, half an Hour), and the Barges would be carried a great Way farther (perhaps beyond *Richmond*) before they had Occasion to drag, which they now frequently begin to do a little above *Putney*. The Expence thus saved would much more than compensate any small Toll or Duty laid upon them, for deepening and otherwise improving the River within the Jurisdiction of the City.

With respect to Imbankments, we have seen, that where the River is at any particular Place broader above than below, there, instead of being a Detriment, they must be of Service to the River in general*, provided Care is taken to leave a proportional Width and Depth of Channel, and to preserve a sufficient Number of Inlets for the Conveniency of Craft to lie and unload out of the Current. † But, in Imbanking, much Caution should be used not to straiten or narrow the main Channel; for the Effect of a Shoal in the Water-way has been already set forth ‡; And if the River, by being confined, and the Strength of its Current

* Cor. 4.

† The Hint of preserving a sufficient Number of Inlets for Craft, is taken from a Pamphlet, called *The Destruction of Trade*, &c. prognosticated.

‡ Corol. 5.

directed

directed from its first Course, should even remove a Bank from one Place, it might deposit it in a worse.

It must therefore be granted, that partial Enquiries after particular Parts of the River, here and there, serve very little Purpose; and, as may be recollected from recent Experience, tend only to perplex the most Ingenious, by fixing their Attention to one Spot, instead of considering the Effect that any particular Alteration may have on the Whole.

Therefore, without an accurate Survey of the Whole, it may be justly inferred, that no true Judgement can be formed: But if its Breadth, Levels, and Soundings were taken as far up and down the River as necessary, and the Depth, with the Rise of the Tide, shown every where with respect to one horizontal Curve † (an Operation though curious, yet, with Care and a good Instrument, very practicable, it being certain, that Levels may be taken to less than half an Inch in a Mile ‡), Men of Science and Genius could at once judge with Perspicuity and Justice, from the Data obtained by such a Survey; and from knowing, for Example, how much High-

† This Expression is used instead of horizontal Line; because, if three Points, each a Mile distant from the other, are in the same straight Line, and that Line truly horizontal at the middle Point; yet, on Account of the Curvature of the Earth, the Points at the Extremities of the Line will be eight Inches above the Level of the middle Point.

‡ Several Levels, taken by the Author, for many Miles together, particularly in a Survey for bringing Water from the *River Colne to London*, were checked to much less than half an Inch in a Mile.

water Mark at *London Bridge* exceeds that at *Richmond*, it could be ascertained what additional Rise and Velocity might be expected from an enlarged Water-way. That there must be a considerable Difference in the Levels upward, is evident from the Velocity of the Tide; though, without Experiment, no just Idea can be formed of the Matter. For, in some higher Parts of the Thames, where there is no Tide, it appeared from an actual Survey †, that a Declivity of two Feet in a Mile produces a Velocity of about two Miles and a half in an Hour; and almost immediately below, where the River is broader and shallower, and consequently has more Friction at the Bottom, with nearly the same Declivity, it only runs about a Mile and an half. This is a striking Example of the Difference between deep Water and shallow; and we may from hence infer, that where the River is deep, and of a proper Breadth, the Tide runs, with the same Declivity, much faster than where it is otherwise; and likewise, that as the Water is continually deepening on the Flow of the Tide, it will require less Fall to go with the same Velocity towards High-water, than at first; which is a strong Argument in Favour of its running farther upwards than might have been imagined. To form Conjectures, however, as to the Difference of the Levels between *Gravesend* and *London*, or between *London* and the

† Taken by the Author between *Hampton-Court* and *Walton-Bridges*.

Point of Stagnation, or to produce Arguments to support such Suppositions, and deduce Inferences from them, would answer very little Purpose, since every such Enquiry can alone be properly determined by actual Mensuration.

To conclude, It is presumed, that, from the whole of this Dissertation, the Research here recommended will appear to be the only certain Means of judging, with Truth and Precision, concerning the State of the River; by which, not only what is at present amiss may be rectified, but future Inconveniencies, in a great Measure, avoided. Expedients might possibly from thence be found out, to prevent the River from falling into a worse Condition, even if *London Bridge* should be suffered to stand in its present State: Which, if it does, will exhibit a fair Trial of Skill between Nature and Art; for the River is now struggling very hard under its Fetters, and by tearing up its Bed, at the Fall, to above thirty Feet at Low-water, has already formed an Abyss sufficient to bury twice the Superstructure: Nor will it be at all surprising, if the Islands of floating Ice, furnished by hoary Winter, should act the Part of keen Pioneers, and lend their effectual Aid to shake off and intomb the unsufferable Load, affording a striking Example, of the Consequences which attend the laying impolitic Restraints even upon inanimate Nature. 18 AP 68.

F I N I S.

